NRCS Natural Resources Conservation Service

New Jersey

ENERGY CONSERVATION SERIES:

Conserving Energy in Building Envelope Design

INTRODUCTION

Agriculture in New Jersey is more dependent on farm buildings as part of operations than most other American farming operations. Greenhouses, nurseries, vegetable and fruit producers, and equine farms, all prevalent in New Jersey, make extensive use of enclosed structures for growing and processing their products. Additionally, both of these sectors tend to require significant areas with energy-intensive, tightly-controlled environments. While agricultural buildings are often less energy-intensive than buildings for other uses, significant energy conservation can be realized through proper design and construction of enclosed structures. This document presents an overview of techniques that can improve the energy efficiency of agricultural buildings.

BASICS OF BUILDING ENVELOPES AND ENERGY EFFICIENCY

Buildings lose energy in the form of heat through various mechanisms. Conduction is the transmission of heat through solids such as framing members, wall materials, doors, windows and insulation. Convection is the movement of heat conveyed by fluids, in particular air. Infiltration is the movement of outside air into the building, which displaces the conditioned air on the inside. Moisture movement also influences building energy use. For example, in an air conditioned space in warm, humid weather the air conditioner will work harder to remove moisture that enters the building from outside. Radiation heat transfer is another mechanism for heat loss and is the direct exchange of heat through infrared radiation between two objects. The rate of exchange depends on the relative temperatures and surface characteristics of the objects.

BASIC DESIGN AND MAINTENANCE PRINCIPLES

The building envelope separates the inside, controlled environment from the outside. In a well-designed building, a barrier that includes thermal, air and moisture barriers completely encloses the entire space. The individual components of the barrier should be contiguous (that is, physically touching each other) and there should be no breaks in the barrier (6). See Figure 1.

Air infiltration and the physical characteristics of the various building materials typically account for most of the heat loss through the building envelope. Conductive heat loss is affected by the properties of framing members, insulation and other materials as well as the way in which walls, floors and ceilings are constructed. Thermal bridging is the transfer of heat through the building envelope by poor insulators (such as metal studs). Good construction techniques can minimize thermal bridging. Thermal bypass, breaks in the building envelope that allow air and heat migration, also increases heat loss. Good design, coordination of different contractors during construction, careful installation and proper maintenance can reduce or eliminate thermal bypass problems. In general, the more insulation the better. The specific types of insulation used will depend on the type and use of the building and particularities of the construction. Insulation should be installed so that a reasonably uniform insulation value exists over the entire insulated area. Insulation should be compatible with electrical wiring of the structure and installed according to manufacturer's recommendations. Install vapor retarder with the insulation in accordance with the latest edition of American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals (2).

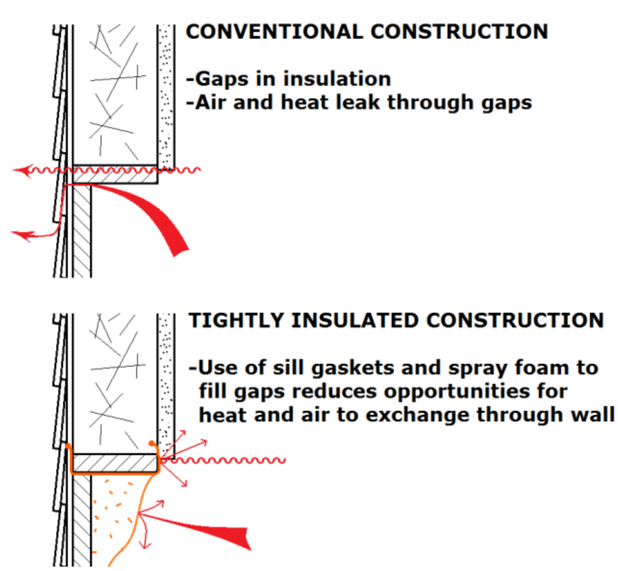
The thermal characteristics of windows and other glazed openings depend primarily on the construction details and the properties of the glazing. Double and triple glazed windows are more efficient than single layer windows, particularly when the space between the layers is hermetically sealed. Low-emissivity glass reduces heat loss by reflecting infrared light (heat energy).

See the USDA-NRCS Conservation Practices Standard No. 672 (7) for further information on NRCS building standards.

Sealing cracks and holes in the air barrier is an important factor in controlling infiltration. The most comprehensive evaluation of energy leakage in building envelopes is a blower door test, which uses an exhaust fan to create low pressure inside the building so that cracks can be detected with a smoke pencil. Inspection of areas that are likely to leak can also reveal many cracks and gaps. These

Figure 1- Airtight Construction

Diagram: C. McKittrick, NJAES



areas include door and window frames, penetrations through the exterior walls (plumbing, wiring, air conditioners, etc.) and fans and vents. The U.S. Department of Energy's office of Energy Efficiency and Renewable Energy has detailed information about air sealing in buildings (10).

Triple-Pane Window Cutaway
PHOTO: US DEPARTMENT OF ENERGY

GENERAL BUILDING ENVELOPE CONSIDERATIONS IN AGRICULTURE

Building envelope energy performance in agricultural facilities is often less of a concern than it can be in residential and small commercial buildings. There are many reasons for this, including:

- Limited use of mechanical cooling (air conditioning)
- Lower heating setpoints or buildings that operate at ambient temperatures
- Higher cooling setpoints and tolerance of higher humidity which permits the use of evaporative cooling in many climates
- Seasonal use of buildings.
- Relatively few windows in many types of facilities
- Daily use cycles

In practice, building envelope performance is a concern in agricultural structures that are climate controlled at least part of the time (7). Apart from greenhouses, which have high heat losses through the building envelope and are discussed below, the areas of greatest concern on farms tend to be specific use buildings, such as milking parlors, animal treatment facilities and packing and handling buildings. The general considerations discussed above apply to these types of facilities. Appendix 1, at the end of this publication, can be useful in selecting the best type of insulation for a specific application.

Very efficient building envelopes that successfully reduce air infiltration can lead to problems with indoor air quality. Building codes typically require minimum fresh air ventilation rates for specific types of building to ensure adequate air quality. Because the incoming air will typically need to be heated or cooled to the desired indoor temperature there is an energy cost associated with fresh air ventilation systems.

Equipment to warm or cool incoming air (depending on the season and the indoor environment) can reduce the energy used for heating and cooling. This may be a heat recovery ventilator (HRV, heat exchanger, or air-to air heat exchanger) which transfers heat from the warmer air stream to the cooler air, or an energy recovery ventilator (ERV) that transfers both heat and moisture between the incoming and outgoing air flows. The effectiveness of specific recovery ventilation equipment is a function of heat transfer efficiency, fan performance, heat transfer capacity and other factors. Energy Star Canada has rating procedures and specific performance data for HRV and ERV equipment. The Air-Conditioning, Heating and Refrigeration Institute (AHRI) has certification standards for ERV and HRV equipment and provides detailed performance data for the equipment it certifies (9). Installing HRV or ERV equipment may be a cost effective energy saving technique for agricultural buildings, depending on the construction, use and operation of the facility.

The heat transmission of building envelope components is expressed by the U-factor, which describes the overall heat transfer coefficient of the assembly. In English units, U is stated as British Thermal Units (BTUs) per square foot per hour per degree Fahrenheit and in Standard International units it is expressed as Watts per square meter per degree Kelvin. The U-factor is typically used for wall, roof and floor assemblies. It is the inverse of the total resistance to heat transfer (R) of the assembly. Because many components of building envelopes are not homogenous (an insulated wood frame wall, for instance, consists of spaced wood studs with insulation between the studs), determining the U-factor for a particular building component may involve more complex calculations based on the R-values and other properties (such as thermal mass) of the individual constituents. The procedures and standards described in the 2009 ASHRAE Handbook - Fundamentals (2) are the basis for most methods of calculating U-factors for building envelopes.

ASABE S401.2 lists recommended U-factors for building envelope components in agricultural buildings (1). There are a variety of sources that list R-values for different building materials (2) (4). Proper installation and ongoing maintenance of insulating materials is essential to ensure that the building envelope achieves the recommended U-factor.

GREENHOUSES

Energy concerns in greenhouses are discussed in detail in the fact sheet from this series, "Conserving Energy in Greenhouse Operations" (11). The materials used to cover greenhouses tend to have high light transmission and poor thermal characteristics. Several strategies can minimize envelope heat losses in greenhouses:

- Consolidating greenhouse growing areas into larger, gutter-connected structures
- Choosing energy efficient coverings
- Using thermal (energy) curtains
- Insulating opaque walls
- Installing insulated doors
- Weather-stripping and caulk at doors, vents and all other cracks, openings and wall penetrations.
- Routine maintenance, including inspection of all wall and roof penetrations, repairing damaged coverings and keeping louvers in good operating condition.

Greenhouse coverings vary greatly in their ability to transmit light and retain heat. Glazing selection affects energy use and crop production. Growers will often need to choose between glazing that is very transparent but doesn't retain heat or a covering that has reduced light transmission and better ability to retain heat. As a general rule, single layer coverings will use 50% more energy for heating than double layer materials. Double-layer acrylic or polycarbonates or double-layer polyethylene films transmit light fairly well and retain heat better than single layer glass or polyethylene.

Energy curtains can reduce greenhouse heat losses by as much as 35%. Multiple curtains can further reduce energy use. Proper installation and routine maintenance are essentially to ensure optimal performance of curtain systems. Repair any holes and tears in the curtain fabric as soon as practical. The edges of curtain systems with walls, other structural members and adjacent curtains should be well sealed. Even small gaps along curtain edges will significantly compromise energy performance.

The rigid materials (acrylics and polycarbonates) tend to be significantly more expensive. Single layer glass provides the highest light transmission level, requires less maintenance and is more durable, but is less energy efficient and can be significantly more expensive. The performance of polyethylene films with infrared opaque (IR) and anti-condensate (AC) coatings depends on the specifics of the greenhouse structure. Energy savings can be 20% or greater, as compared to regular double polyethylene film, with the greatest temperature savings typically seen in low temperature greenhouse with forced air heating systems (3). See Table 1 for specific information regarding the insulation value of some common materials. It is important to know the needs of specific crops for light, heat, and humidity and base glazing selection on these factors.

Table 1- Insulation Value of Common Building Materials

Source: Both (2), Martin (3)

Material	U- Factor
Single (Double) Layer Glass	1.1 (0.7)
Single (Double) Layer Polyethylene	1.1 (0.7)
Twin-Wall Layer Acrylic	0.6
Twin-Wall Polycarbonate	0.6
8" Concrete Block	0.5
Door, Wood, Hollow Core (1.75")	0.5
Door, Wood, Filled Core (1.75")	0.3
Door, Wood, Filled Core (2.25")	0.3
Door, Insulated Steel (1.5")	0.1

LIVESTOCK BUILDINGS

Livestock housing and related buildings use energy primarily for ventilation, and secondarily for heating and lighting. Energy use related to livestock buildings tends to be fairly low-intensity; however, careful design of such buildings before either construction or major renovations can be significant in terms of energy conservation.

To maximize the energy efficiency of livestock buildings to be constructed, be sure framing is designed to accommodate a laminar, linear flow of air throughout the structure, as well as appropriately sized and placed openings for natural ventilation, fan intakes, and exhaust. For further information, see the fact sheets from this series, "Conserving Energy in Livestock Operations" (13) and "Conserving Energy in Agricultural Ventilation" (12). Appendix 1 in this sheet can also be useful in determining appropriate means of insulating such buildings.

In livestock buildings which are heated, properly balancing ventilation, and maintaining the integrity of the building envelope's insulation, is critical to energy efficiency and conservation. Well-insulated and gasketed shutters placed outside of ventilation ports and louvers, as well as movable shutters in roof vents, can help in creating this balance.

LIGHTING

Conserving energy in lighting is closely related to building envelope design. In all applications, lighting energy use is minimized through use of natural light where possible; therefore, building design should emphasize the placement of appropriately sized and insulated skylights. Placement of skylights, similar to planning for appropriate spatial orientation of buildings with respect to climate factors, should be planned to be optimal given the location's latitude.

Selecting lighting technologies which produce the most lumens per watt of all options meeting the needs of the operation, is the most important factor in optimizing energy use by any artificial lighting. Task lighting, similar to optimizing energy use, is important so that the area where work is actually occurring will be lit. Ergonomic placement and design of lighting control devices can also be important, so as to ensure that workers will always turn lights on and off as appropriate.

The fact sheet in this series, "Conserving Energy in Agricultural Lighting" (14), discusses lighting energy optimization in more detail.

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FURTHER READING

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This publication was developed by Rutgers Cooperative Extension, for USDA Natural Resources Conservation Service in support of Agreement No. 68-2B29-11-150.

Cooperating Agencies: Rutgers, The State University of New Jersey, U.S. Department of Agriculture, and County Boards of Chosen Freeholders. Rutgers Cooperative Extension, a unit of the Rutgers New Jersey Agricultural Experiment Station, is an equal opportunity program provider and employer.

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Appendix 1- Insulation Type Selection

Source: US Dept. of Energy (8)

Form of Insulation	Where Applicable	Installation Methods	Advantages
Blanket	Unfinished walls, incl. foundations, ceilings	Fitted between studs, joists, and beams	Suited for standard stud and joist spacing. Simple install.
Foam Board	Floors, ceilings, walls, unvented roofs	Must be covered by gypsum or siding	High insulating value, may be installed continuous
Loose Fill	Unfinished cavities, finished cavities	Blown into place	May be installed on already finished buildings
Reflective	Unfinished surfaces	Fitted between studs	Simple install, prevents downward heat flow
Insulating Concrete	New Construction	Part of structure	High thermal resistance
Fibrous	High-temperature ducts	Built into ducts	High temperature tolerance
Sprayed Foam	Enclosed wall cavities	Compressed Air	Good around obstructions